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A Stage-of-Processing Price System

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A STAGE-OF-PROCESSING PRICE SYSTEM

Introduction

A Stage-of-Processing (SOP) price system is an ideal framework with which to follow the evolution of relative prices, their interaction, and their effects on general price movements. It is not so much a theory of inflation as a theory of price adjustment, yet it can reinforce or weaken the role of the Phillips curve in a macro model depending on the market structure of an economy. Joel Popkin (1973, 1977, 1978) is one of the principal proponents of this approach.

The approach is described here by focussing on two aspects: 1) the framework, which boils down to the classification of industries by Stage-of-Processing rather than by the "Standard Industrial Classification" (SIC), and 2) the introduction in this framework of pricing behaviour specific to the industry at each stage. The benefits to be drawn from the combination of these two aspects can then be seen, as can the limitations of this approach. Finally some of the empirical work done in Canada in this area is described.

A System of Aggregation

An SOP price block involves the specification of a price equation for products at all stages of production. One aspect of the approach is the method of aggregation which establishes the definition of these products and which constitutes the SOP framework. The description of an SOP framework is best achieved if one first pictures the use-matrix of an input-output table (see Table 1). Each column of the matrix describes the inputs used by each industry, including the products from other industries as well as its own capital and labour; i.e., all the elements of cost incurred in its production process. Fortunately, for practical applications such a matrix can be made triangular. Essentially this means that at an early stage of production the industries that utilize mainly capital and labour inputs (rather than inputs from other industries) are included. The service and extraction industries are examples. At the next stage of transformation, industries using the preceding stage of production output and primary inputs are found. At higher stages of production, the production function gets more and more complex, requiring inputs mainly from earlier stages. This property is critical to the SOP approach as it allows a clear and unidirectional transmission mechanism and a grouping of industries with similar inputs which should reduce the

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This paper is one of the series of working papers for "Price Flexibility and Business Cycle Fluctuations in Canada - A Survey", a study prepared by the Research Department of the Bank of Canada for the Royal Commission on the Economic Union and Development Prospects for Canada. These research papers were all completed in early 1984.

Table 1

Inputs to 24 Industry Gross Output (1979) (Millions of $)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1. Communications	296.6	1019.2	20.8	19.9	31.5	360.2	973.9	23.6	33.1	108.4	97.0	68.9	7.4	24.0	34.8	78.8	66.6	93.9	19.6	69.7	79.3	1279.3	119.1	0
2. Serv. to bus. FIRE ex housing	279.4	5238.6	4572.9	159.2	213.0	1022.4	3430.2	654.3	184.6	555.1	474.6	372.9	569.5	244.2	241.9	210.1	1029.2	252.8	108.3	561.5	452.0	1941.1	2552.6	267.7
3. Mineral fuels	1.2	95.4	30.9	10936.7	604.9	179.8	137.8	58.6	741.9	266.2	48.3	34.4	2.0	24.0	134.5	13.7	29.7	18.2	100.9	16.7	68.7	34.8	50.5	0
4. Petroleum & coal products	41.8	203.9	51.1	248.8	300.6	1604.3	780.1	322.1	187.3	746.3	53.1	63.0	119.3	48.5	392.6	16.1	47.9	33.6	123.1	670.4	127.2	525.3	744.0	0
5. Elec. power, gas, other util.	37.2	338.4	146.2	80.0	44.2	163.4	771.4	244.9	297.7	288.3	100.2	117.7	7.1	104.8	424.5	43.0	89.2	27.1	119.6	215.1	152.7	226.6	57.7	0
6. Trans. storage & margins	155.3	98.8	39.6	454.5	92.5	11630.6	760.8	248.5	475.8	355.7	286.8	157.2	436.2	202.3	411.2	89.3	347.4	431.5	188.2	228.4	721.2	1745.9	1106.7	0
7. Trade & pers. services	88.1	146.5	42.1	39.5	30.0	411.8	493.2	151.9	488.3	306.1	437.1	393.5	47.1	189.0	223.6	164.7	266.6	4783.0	66.4	462.2	586.5	879.0	2120.4	0
8. Mines & incidental services	.5	4.8	400.9	4.2	43.5	10.1	7.2	428.4	3214.4	341.4	264.8	6.0	2.0	.4	29.1	2.7	2.5	36.9	210.8	187.9	15.1	10.3	1953.1	0
9. Primary metals	.3	1.9	44.3	9.1	14.3	41.0	53.2	189.0	3079.5	525.9	3920.5	30.7	1.5	16.8	85.4	992.4	1749.2	185.0	79.6	19.8	18.9	3.9	1444.8	0
10. Chemical prod. & misc. mfg.	23.3	13.5	43.9	267.6	1.3	69.0	237.0	172.1	148.5	2944.3	349.3	1675.0	12.7	107.5	630.5	268.7	208.4	1392.3	134.1	802.2	199.5	330.5	908.4	0
11. Metal fabr. & machinery	5.1	15.7	73.9	25.3	1.5	93.0	191.5	170.6	341.4	225.4	2744.3	138.8	61.9	116.4	64.1	372.8	1317.2	3377.2	55.6	191.7	546.3	40.0	4554.3	0
12. Rub. plast. leather, text. cloth	5.5	3.1	1.6	4.1	0.3	184.6	198.2	13.5	10.8	260.6	193.6	3904.7	8.5	35.6	138.5	79.1	1588.7	1127.4	35.8	86.7	193.1	154.9	1077.6	0
13. Forestry	.2	.9	.1	.1	0	6.7	16.6	.4	.4	1.6	.5	.3	485.1	2611.5	1160.3	.1	.4	.9	.1	22.7	.4	17.6	19.0	0
14. Wood	.3	2.6	1.9	.4	.1	3.2	105.1	5.2	22.2	34.8	61.2	15.8	.9	990.1	703.5	19.4	75.6	36.2	11.2	16.5	11.1	3.7	2692.4	0
15. Paper & allied products	2.9	15.3	3.8	15.0	.4	15.8	510.8	24.2	17.7	233.4	92.1	204.0	1.1	51.8	1725.4	70.1	48.7	1452.6	82.4	13.6	739.3	172.9	388.0	0
16. Electrical products	172.3	10.9	5.0	1.1	.9	51.4	34.6	14.5	106.0	72.1	226.4	14.5	2.1	9.1	8.5	1155.6	392.4	804.9	8.7	21.0	12.3	21.7	1550.6	0
17. Trans. equipment	2.6	5.1	6.4	1.8	1.0	623.0	27.2	34.1	53.4	23.8	340.3	53.4	9.5	11.1	10.2	47.8	6901.9	925.1	5.1	57.1	26.1	81.1	250.1	0
18. Print. pub. operating supplies	228.5	2505.5	391.5	143.7	169.9	750.6	1368.8	1245.0	746.6	438.7	465.2	349.3	585.5	481.0	598.3	160.3	561.5	1868.0	303.6	388.7	607.1	2794.6	761.5	0
19. Non-metal mineral products	.2	1.0	.8	3.7	.1	22.4	16.3	54.1	151.7	70.4	98.2	25.1	.7	41.7	47.6	42.0	164.0	125.6	566.8	14.1	237.4	18.1	2482.0	0
20. Agriculture, fish. hunt. trap.	.2	2.6	.1	.1	0	9.5	438.0	.2	.1	12.7	.3	177.0	.3	22.1	21.5	.1	.1	101.8	.1	902.2	8940.4	216.3	26.2	0
21. Food, beverages & tobacco	1.1	2.5	2.1	2.6	1.0	14.1	48.9	6.3	22.8	189.3	21.8	115.8	1.2	10.5	42.4	7.5	10.5	683.0	3.9	1443.8	5102.0	2167.0	84.8	0
22. H&Ed. rec. acc. rest. tour. advtg.	308.9	1243.7	56.8	126.2	43.3	404.7	1778.2	71.1	57.6	613.0	310.2	310.7	11.9	51.5	96.9	171.7	244.3	185.6	60.7	6.0	778.8	2452.7	270.1	0
23. Construction & furniture	180.1	226.5	448.2	158.9	292.8	680.0	207.9	86.5	90.7	77.0	51.8	34.0	66.6	85.8	84.1	27.2	57.6	19.1	22.1	328.1	64.2	115.2	174.7	3265.8
24. Housing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25. Total intermediate inputs	1831.5	11196.3	6384.8	12702.4	1887.5	18351.5	12586.7	4218.9	10472.6	8690.5	10637.7	8262.5	2440.1	5479.8	7309.7	4033.2	15199.4	17961.6	2306.8	6726.6	19679.5	15232.2	25388.4	3533.5
26. % on or above diagonal	16.2	55.9	72.4	89.5	63.3	81.5	58.4	50.5	83.1	74.1	82.5	84.3	72.1	86.0	87.6	88.7	93.2	93.8	96.2	73.6	95.7	99.2	100.0	100.0
Unallocated inputs	14.7	99.5	2.1	.2	11.3	114.8	30.3	1.7	.2	7.2	2.9	224.4	11.3	0	8.9	.3	0	86.8	1.8	13.6	651.6	436.2	137.7	0
Net indirect taxes	-179.6	1343.8	516.2	-1048.9	-43.7	438.7	962.8	147.9	95.5	131.7	98.6	76.6	66.0	65.3	37.9	43.4	33.1	1115.0	72.5	-170.4	39.2	766.6	1830.6	5724.4
Labour income	4153.2	14133.8	919.1	487.1	1975.5	8225.9	19389.4	2657.4	2752.5	2733.8	4892.6	3787.7	1392.4	2250.3	2763.6	2152.5	4029.1	1746.5	1111.5	1173.3	4063.6	5988.9	13106.1	0
Capital income	2730.0	11368.3	6648.2	329.7	4863.3	3626.9	9017.8	3840.1	1483.1	1884.8	2240.1	1477.7	536.9	1181.0	2341.0	1056.1	1501.4	750.1	743.6	7627.2	2748.8	5731.8	5461.2	11801.2
Gross output	8549.8	38141.7	14470.4	12470.5	8693.9	30757.8	41987.0	10866.0	14804.0	13447.9	17872.0	13829.0	4446.9	8976.4	12461.0	7285.4	20763.0	21660.1	4236.3	15370.3	27182.7	28155.7	45924.1	21059.1
Value added/gross output (%)	80.5	66.9	52.3	6.5	78.7	38.5	67.7	59.8	28.6	34.3	39.9	38.1	43.4	38.2	41.0	44.0	26.6	11.5	43.8	57.3	25.1	41.6	40.4	56.0

problem of the heterogeneity of the production function inherent to aggregation, since the cost function of the industry at higher stages of production involves input costs coming from downstream. The ordering of the industries presented in Table 1 is a very rough attempt at making the matrix triangular but one can still see the importance of this characteristic for the Canadian economy. The bottom line of this table gives the share of primary inputs in total cost for each industry while line 26 gives the proportion of intermediate inputs on or above the diagonal. In this ordering, 85% of intermediate sales are on or above the diagonal, while using the SIC -- the usual way of presenting the input-output table data -- only 67% are.

Pricing Behaviour

A full-scale SOP price block involves the specification of a price equation for the products of each stage of production such that the equation reflects the prevailing market conditions for the industry it defines. The specification need not include only its own-cost function or even include it at all. It can be anything from a model of a price-taker, to that of a price-setter, to a simple markup rule. If an industry is a price-taker, the price is determined exogenously and the cost function determines the quantities (or the profits in the short run). In general the price equation will combine the supply and the demand curves for the product.

In some SOP price systems, all the supply variables at each stage of production are specified, including wage rates and factor demands. Also, indicators of specific demand pressure such as inventory and orders are used. It can turn into a rather complex model of supply and demand at a very disaggregated level.[1] For the time being, however, the focus will be on the system of price equations per se.

Advantages

The advantages of a disaggregated system of SOP pricing in the determination of final prices are numerous. They essentially stem from the fact that explicit account is taken of the impact of industry-specific price behaviour, rigidities and bottlenecks on the final prices. More conventional price equations involve only labour and capital costs. They could be viewed as quasi-reduced forms of a disaggregated price system like the one just described which explicitly account for material inputs. However, as material-input prices are also presumed to be functions of primary inputs they eventually disappear in a chain of substitution as do

1. One should note that if the level of disaggregation is very fine there is no point in making the system recursive to begin with and that the approach is very close to an input-output price model with flexible coefficients and endogenous primary input prices.

all the pecularities of price determination in various markets at the early stages of production. It is suspected that the aggregate approach is one reason why the energy-price shocks and the other surges in raw-materials prices that occurred in the seventies were not appropriately captured by the final-price equations in existence at that time. With an articulated SOP price system it is easier to follow the impact of a natural-resource-based indirect tax increase on finished products. The incidence of a change in the value of the dollar could also be better assessed when it is allowed to influence the price of specific commodities that are sold not only as final products but also as intermediate products.

The reaction of model builders to the shortcomings of final-sales price equations that do not include material costs has been the ad hoc introduction of raw-material price terms. The approach, however, has not been systematic and is based on the questionable assumption of homogeneity of pricing behaviour across industries.

A model of the determination of the general price level involves a set of price equations (unless we are talking about a complete reduced form), but should also have a link with the quantity of money in circulation. This link is usually part of the model of general economic activity, representing all the supplies of and demands for products that are influenced by money through asset positions and interest rates. Thus, to fully appreciate the advantages of an SOP price system it is better to place the discussion in the context of a general macro model. The role of an SOP-type system of relative prices in the determination of the general price level is one of a set of filters through which the quantity of money ultimately influences specific prices. The porosity of the filter depends on the characteristics of the market at each stage of production; the more rigidities there are in the transmission process the more quantity adjustments precede the general price-level adjustments. The Canadian economy has many apparent instances of such rigidities. Many markets are exposed to international competition and we have our fair share of regulated prices. According to Stuber (Working Paper W18) roughly 18% of total GDP is currently generated in the tradeable-goods sector, 25% in the regulated sector and 15% in the public sector, leaving 42% for the non-regulated sector. The consequences from model simulation of demand management could be significant as domestic demand shocks cannot impact directly and immediately on an important part of activity. An interesting side benefit related to this aspect is that with a proper specification of price equations for exposed sectors the model would have some of the characteristics of a Scandinavian model, especially if wage determination was allowed some imitation effects across sectors.

Tables 2 and 3 have been built in the context of Table 1 in order to give an impression of how these aspects of the Canadian economy would be reflected through an SOP price block. Consider the openness aspect and how it would affect the general price level. Presumably the price of the

Table 2

Sources and Uses of Total Supply (1979) (Millions of $)

	1 Inter-mediate sales	2 Final domestic sales (1)	3 Exports	4 Imports	5 Final sales (2+3-4)	6 Total sales or production (5+1)	7 Total supply (6+4)	8 Foreign involvement % ((3+4)÷7)
1. Communications	4925.5	3634.9	209.9	220.6	3624.2	8549.8	8770.3	4.9
2. Serv. to bus. FIRE ex housing	25588.0	14210.2	1177.3	2833.9	12553.7	38141.7	40975.6	9.8
3. Mineral fuels	13629.7	720.2	5944.2	5823.7	840.7	14470.4	20294.1	58.0
4. Petroleum & coal products	7450.5	3976.0	1530.7	486.7	5020.0	12470.5	12957.2	15.6
5. Elec. power, gas, other utilities	4096.9	3864.4	745.1	12.5	4597.0	8693.9	8706.4	8.7
6. Trans. storage & margins	20664.3	6200.2	4549.9	656.7	10093.4	30757.8	31414.5	16.6
7. Trade & personal services	12816.8	27815.2	2052.3	697.4	29170.2	41987.0	42684.4	6.4
8. Mines & incidental services	7177.0	179.9	4886.0	1371.3	3694.6	10871.6	12242.9	51.1
9. Primary metals	12506.9	696.8	5327.7	3727.3	2297.1	14804.0	18531.4	48.9
10. Chemical prod. & misc. mfg.	10939.6	6346.1	2842.4	6680.1	2508.4	13448.0	20128.1	47.3
11. Metal fabr. & machinery	14724.2	10019.8	5034.7	11906.7	3147.8	17872.0	29778.7	56.9
12. Rub. plast. leather, text. cloth.	9306.2	8971.7	1867.4	6316.3	4522.8	13829.0	20145.3	40.6
13. Forestry	4346.0	107.2	99.6	106.0	100.9	4446.9	4552.8	4.5
14. Wood	4813.4	501.7	4326.2	664.9	4163.0	8976.4	9641.3	51.8
15. Paper & allied products	5881.1	777.4	6855.0	1052.5	6579.9	12461.0	13513.5	58.5
16. Electrical products	4696.6	5112.9	1436.1	3960.2	2588.8	7285.4	11245.6	48.0
17. Transportation equipment	9497.4	14602.9	12836.3	16173.0	11266.3	20763.6	36936.6	78.5
18. Print. publ. operating supplies	17913.3	4478.2	179.5	909.9	3747.8	21661.1	22571.0	4.8
19. Non-metal mineral products	4183.9	447.5	453.9	849.1	52.4	4236.3	5085.3	25.6
20. Agriculture, fish. hunt. trap.	10872.1	2095.1	3751.5	1348.3	4498.2	15370.3	16718.7	30.5
21. Food, beverages & tobacco	9984.8	16958.7	3275.4	3031.5	17202.7	27187.4	30218.9	20.9
22. H&Ed. rec. acc. rest. tour. advtg.	9654.7	18523.4	5.0	27.3	18501.0	28155.7	28183.1	0.1
23. Construction & furniture	6844.9	39202.7	184.2	307.7	39079.2	45924.1	46231.8	1.1
24. Housing	0	21059.1	0	0	21059.1	21059.1	21059.1	0
Subtotal	232,514.0	210,502.0	69,570.3	69,163.4	210,909.0	443,423.0	512,586.0	27.1
Unallocated inputs	1,857.7	543.9	4,388.9	6,790.6	-1,857.7	0		
Net indirect taxes	12,163.3	11,918.7	721.0	-3,012.0	15,651.7	27,815.0		
Labour income	105,886.0	40,874.7	0	0	40,874.7	146,760.0		
Capital income	90,990.2	4,440.8	0	0	4,440.8	95,431.0		
Total	443,411.0	268,280.0	74,680.2	72,942.0	270,019.0	713,429.0		

(1) Includes inventories

products originating in the tradeable-goods sector would be largely determined by foreign variables including the exchange rate. This is, of course, a testable assumption that should be verified in the process of building the model, but for the purpose at hand we will consider various definitions of the tradeable-goods sector over a range of possibilities within which the actual result should fit. This is done in Table 2, which gives the distribution of total supply (domestic production plus imports) between intermediate and final sales (domestic and foreign), by looking at the proportion of the transactions, in buying or selling total supply, that take place in foreign markets. Three cut-off points were selected (15%, 30% and 45%) and used in Table 3.

The importance of the role of prices in the tradeable-goods sector on the GNE deflator partly depends on the proportion of final sales supplied by that sector (see Table 3). But it could also depend on the amount of tradeable-goods input in non-tradeable sector output. If we account for only the direct uses, this proportion rises to 47%, 31% or 26% depending on the degree of involvement in foreign markets; indirect uses would affect the final prices with longer lags. In the long run, an SOP price block would account for the full impact on price and quantity. The importance of this phenomenon should determine, to a certain extent, the channel through which a domestic demand shock will affect prices. It should increase the role of the exchange rate and decrease the role of the Phillips curve in the early stages of adjustment.

Table 3

Distribution of a Dollar Spent on GNE in 1979

Proportion going directly to (1)			
Government (indirect taxes) (2)		5.8%	
Persons (remuneration) (3)		16.8%	
Business (sales at producer's price)		78.1%	
of which...	37.2%,	21.9%,	17.6%
goes to the tradeable-goods sector			
defined at more than...	15%,	30%,	45%
degree of involvement in foreign markets			

(1) These three proportions do not total 100% because of unallocated inputs.

(2) Includes only the indirect taxes paid at the final-sales level. The net indirect taxes paid at the point of intermediate sales are part of producer's cost. Total net indirect taxes are 10.3% of GNE.

(3) Mainly remuneration from government.

So the model response to demand shocks should be improved by the integration of an SOP framework in a macro model. It is also evident from what has been said earlier that it makes it possible to handle supply shocks that could not be dealt with before. However, the full benefits of

the supply response can be obtained only if the demand for factors is disaggregated in a consistent fashion.

Limitations

As in any other attempt at trying to enrich a model through disaggregation, the difficulties with an SOP price block stem from its size; the larger the size of econometric models the more likely they are to become a black box. In the case of SOP, however, there are special difficulties.

First, the data have to be generated and updated by the model builder to fit his specific needs. Given that there is no SOP data aggregation readily available, it has to be derived from a multitude of sources implying all kinds of assumptions for consistency between sources. Furthermore, given that the benchmark for the whole data generation is most likely the input-ouput tables, which are published with a lag of three to four years on an annual basis, the data need to be extrapolated and interpolated for use in a quarterly model.

Second, there are the modelling problems themselves. Once a model builder starts to use an SOP approach his propensity to expand the size of his model rises. The problem of where and how to short-circuit his model will come up unless he puts no constraints on the model size. The difficulties associated with the building, maintenance and operation of very large models are not enumerated here, but there is certainly a trade-off between the shortcomings of small but incomplete and large, all-encompassing models.

Frequently, models are short-circuited by introducing a different level of aggregation in the price block than in the factor-demand block. The level of aggregation of the price block is normally in line with the demand side which is typically more disaggregated than the supply side. The difficulty here is that the homogeneity conditions between prices and costs could not result from a strict theoretical derivation. In other words, there could be a lack of consistency in the behaviour of the firm built into the model, such that the actual income distribution would never match that at equilibrium. The problem of inconsistent theory between blocks is especially acute in large models; it is not necessarily introduced by bad design but as a result of numerous little slips at the time of estimation.

SOP in Canada

To our knowledge there are no full-scale SOP models in Canada. There was an attempt to build one at the Economic Council of Canada under the supervision of J. Popkin but it was not completed. There are, however, many model builders who claim that some SOP features have been built into their price block, because they have introduced some crude and

intermediate product prices in their final-sales price equations. In most instances, they rely heavily on data from input-output tables in order to set the relationships between prices, but there is no explicit effort to aggregate industries by stage of processing to achieve a triangular system. Moreover, the very few who attempt to specify the pricing behaviour of earlier stage-of-processing industries assume that input prices are exogenous. In the case of the Canadian economy it could be an acceptable assumption for many prices, but again it is an empirical and testable question.

The Informetrica Model (TIM) (or Candide which has a very similar price block) is a very good example of a Canadian macro model with built-in SOP features. Final domestic demand deflators (or final purchasers' prices) are a weighted sum of industry gross output prices, imports, and final demand tax rates. Producers' prices are themselves determined with an explicit use of input-output information on inter-industry flows accounting for material and primary inputs. The input-output coefficients are fixed and the value-added real products are also a fixed proportion of gross output. The pricing decision ultimately takes place at the level of value-added prices (for non-price-taker producers) such that the behavioural equations remain relatively simple; price and quantity adjustments for the primary endogenous elements of the supply block, capital and labour, are well specified (see G. Paulin's working paper (W13) for a more detailed description). The separability assumption between the capital-labour bundle and material inputs, and the limits put on factor substitution could be a little restrictive. However, it was probably the price that had to be paid for such a high degree of disaggregation. Such a price system is nevertheless capable of handling a great variety of shocks originating from within the price block itself (exogenous price shocks, productivity, indirect taxes etc.) or from outside and of supplying most of the benefits of the SOP approach that were stressed earlier.

The explicit accounting for differences in sectoral pricing behaviour and price rigidities is meant to introduce a more plausible description to the adjustment process but it is not the only element that imposes the adjustment pattern. In TIM, for instance, the choice of making producers target for a return on capital that is proportional to the capital/output ratio and user cost of capital introduces a particular pattern in the price response to an interest rate change. A rise in interest rates will raise the cost of capital before it reduces the capital/output ratio. It will cause at least a temporary rise in prices. The evolution of the price movement hinges heavily on the response of investment to interest rates in the factor demand equation.

Conclusion

In general the same SOP price block in different models will not produce the same description of the inflation process. This occurs

because other critical relationships like the implicit Phillips curve, the exchange rate equation, and the money demand equation are also important in determining the inflation process and vary from model to model. The introduction of an SOP price system in a macro model should result in a more plausible description of the dynamics of price adjustment in the sense that the diversity of responses will parallel more closely the diversity of the shocks.

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